Topic E – Enviro Chemistry Part 7 – Soil

IB Chemistry

Topic E – Enviro

Hodder Ed - Talbot

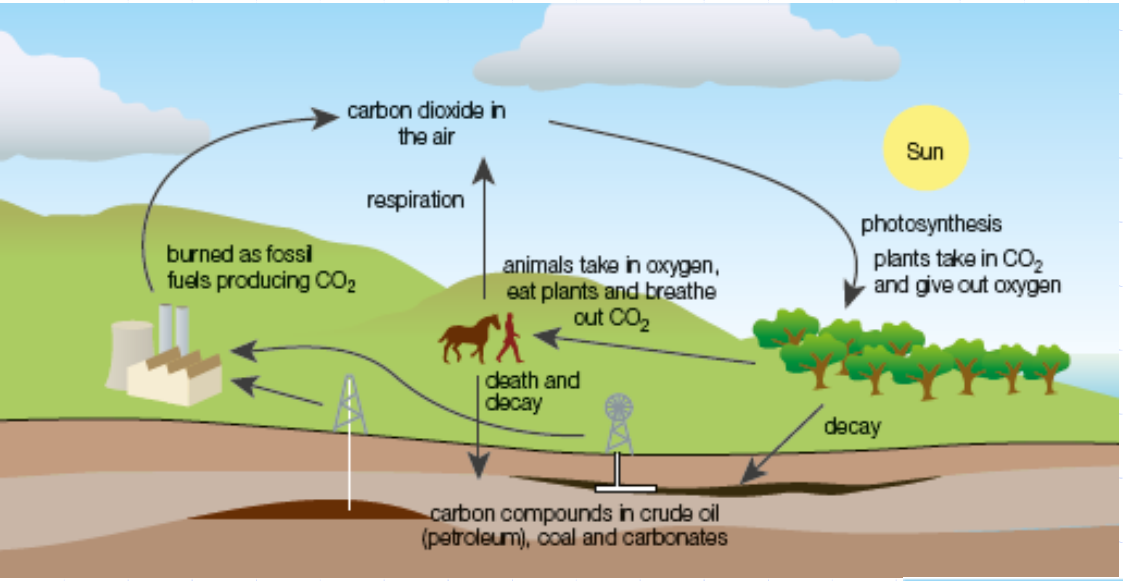
E7 Soil - 2.5 hours

- E.7.1 Discuss salinization, nutrient depletion and soil pollution as causes of soil degradation.(3)
- E.7.2 Describe the relevance of the soil organic matter (SOM) in preventing soil degradation, and outline its physical and biological functions. (2)
- E.7.3 List common organic soil pollutants and their sources. (1)

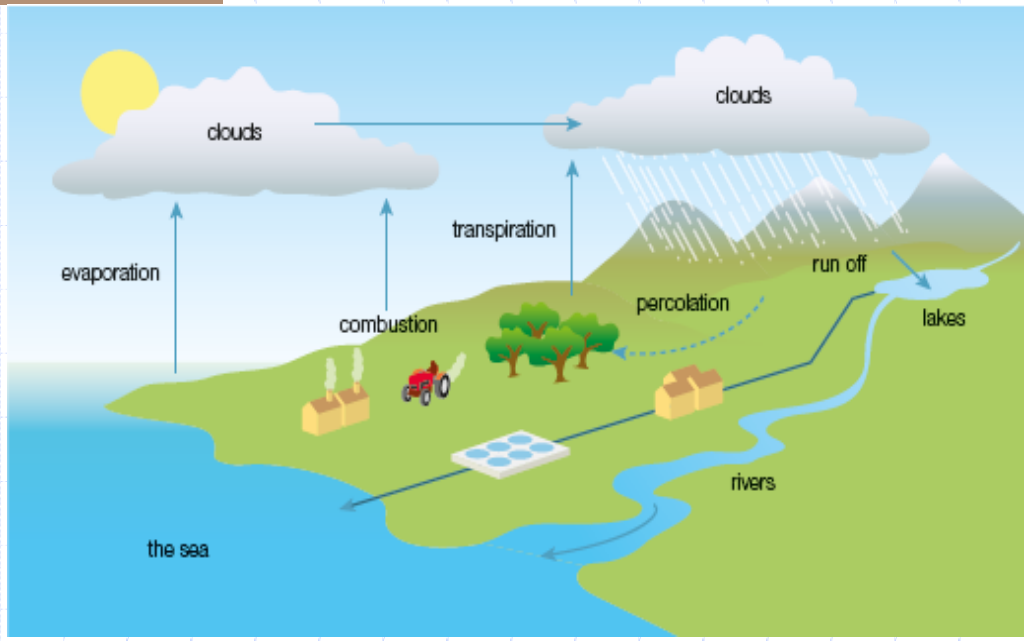
E7.1/2 – Salinization & SOM

- E.7.1 **Discuss** salinization, nutrient depletion and soil pollution as causes of soil degradation. (3)
- E.7.2 **Describe** the relevance of the soil organic matter (SOM) in preventing soil degradation, and **outline** its physical and biological functions. (2)
- Soil is a chemical mixture formed as rock is gradually weathered down to form ions in aqueous solution
- Soil plays a part in cycles such as the **water cycle**, **carbon cycle**, and the **nitrogen cycle**.

E7.1/2 – Carbon and Water Cycles



The carbon cycle



The water cycle

E7.1/2 – Soil Composition

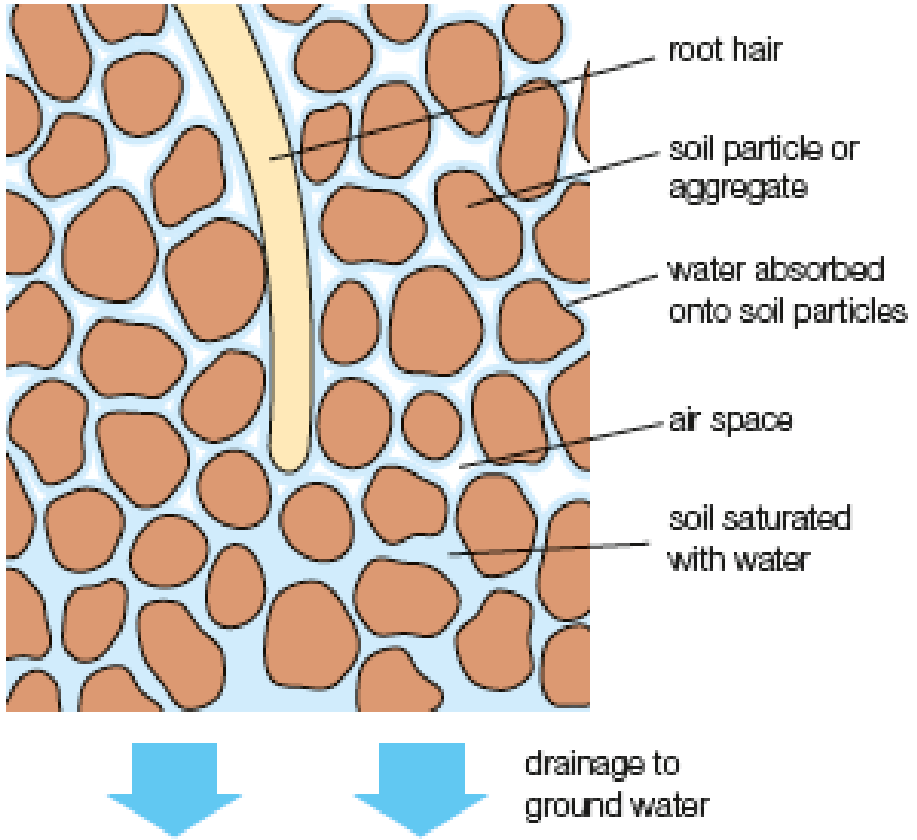
- Soil is composed of organic and inorganic components in varying proportions
  - **Organic component** is called the **humus** and consists of plant material that has been partly decayed by bacteria and fungi
  - **Inorganic component** includes mineral particles (gravel, sand, silt, and clay), water, and air.
  - Water trapped between soil grains contains ions (from dissolving of minerals) which can be absorbed by plant roots.
    - This liquid containing dissolved ions and organic substances, is called the **soil solution**

E7.1/2 – Soil Composition

- Soil supports a variety of living organisms, including bacteria, insects and worms which by growth and decay and the circulation of water and air, modify the soil structure.
- Composition by volume

of typical surface soil:

  - 45% inorganic (rock)
  - 5% organic
  - 25% water
  - 25% air



E7.1/2 – Soil and Water

- The effectiveness of soil to be used for agriculture is strongly determined by drainage.
  - Soggy soil: sticky, difficult to plow and plant, contains too much organic matter
  - Water is essential for plant growth
  - Surface tension between water and soil grains also help to hold the soil together.

7.1/2 – More than soil

- **Below the soil**:
  - Bedrock may contain porous rock, such as limestone (can store water) which are called aquifers
  - Other rocks (such as granite) are impermeable (non-porous) and prevent the flow of water
- The combination of water stored in soil spaces and aquifers is called **groundwater**.
  - When soil drains the water enters the groundwater where it will eventually work its way, via underground channels or through pores of the aquifer, to rivers

E7.1/2 – Soil Organic Matter

- Soil contains rotting organic matter in various stages of decomposition
  - Early states of decomposition:
    - Plant tissue (cellulose): broken down into shorter polysaccharides
    - Animal tissue: broken down into their proteins
  - Further decay:
    - Breaks polysaccharides into simpler sugars and proteins into amino acids
  - When soil is aerated
    - Aerobic bacteria and fungi can decompose most of these molecules still further, forming CO_2 and H_2O

E7.1/2 – Soil Organic Matter (SOM)

- **Soil Organic Matter (SOM)** is beneficial to soil in the following ways:
  - Products of partial decomposition replenish the soil by turning large molecules to smaller ones and soluble ones which plant foots can take up
  - Partially decayed organic material helps to hold soil together. When soil is bound together, water (and thermal) retention is improved
  - Dark-colored SOM-rich soil absorbs heat better than lighter-colored (low SOM) soil

E7.1/2 – Formation of Humus

- In wet soils, O_2 is less able to reach the organic material. As a result, anaerobic bacteria take over, and form more complex organic compounds such as phenols and carboxylic acids
  - These are 'humic substances' and the mixture is called **humus**
  - In cold/wet climates. Up to 95% organic matter known as 'peat soils.'
- The phenols and carboxylic acids in the humus (weak acids) help to buffer the soil pH
  - Important since pH affects the solubility of metal cations in the soil

E7.1/2 – Formation of Soil

- Soil can be formed by both **physical** and **chemical** weathering.
- **Physical Weathering**:
- Soil is a mixture of weathered rock particles, organic matter, air, and water. Bellow is bedrock.
- This is the upper layer of the Earth's crust
- Rock faces high pressures and temperatures which cause it to expand and contract, cracking, and as a result weakens and possibly crumbles.
- Called 'physical weathering' as they do not change the chemical composition of the rock, just break them into smaller fragments.

E7.1/2 – Chemical Weathering

- **Chemical Weathering** occurs when the rock is attacked by various chemical substances, and new materials are formed.
- The most common weathering helps to break bedrock down into soil grains. The following two processes can be used:
  - Oxidation
  - Acid-carbonate reactions

E7.1/2 – Chemical Weathering

- **Oxidation**:
  - Catalyzed by microorganisms such as the bacterium Thiobacillus thiooxidans

$2FeS_2(s) + 7½O_2(g) + 7H_2O(l) \rightarrow 2Fe(OH)_3(s) + 4H_2SO_4(aq)$

- **Acid-carbonate reactions**:
  - Limestone rocks are attacked by rain water containing carbon dioxide (H_2CO_3)

$CaCO_3(s) + H_2CO_3(aq) \rightarrow Ca^{2+}(aq) + 2HCO_3^-(aq)$

  - Silicate minerals are broken down in a similar way:

$Mg_2SiO_4(s) + 4H_2CO_3(aq) \rightarrow Mg^{2+}(aq) + 4HCO_3^-(aq) + H_4SiO_4(aq)$

E7.1/2 – Soil Degradation

- **Soil degradation** refers to damage to the soil, which reduces its ability to support crops. Sources of soil degradation include **salinization**,
  - Nutrient depletion
  - Chemical pollution

E7.1/2 - Salinization

- **Salinization**:
  - The build-up of salts in the soil often becoming toxic to plants.
  - Can arise from
    - Irrigation: water is diverted from waterways to farmland to support crops where rainfall is limited. The irrigation water may contain some dissolved salts.
    - The natural water table:
  - The water transports salts to the soil as they are dissolved. As the water evaporates, the salt is left behind and can build up over time.

E7.1/2 – Nutrient Depletion

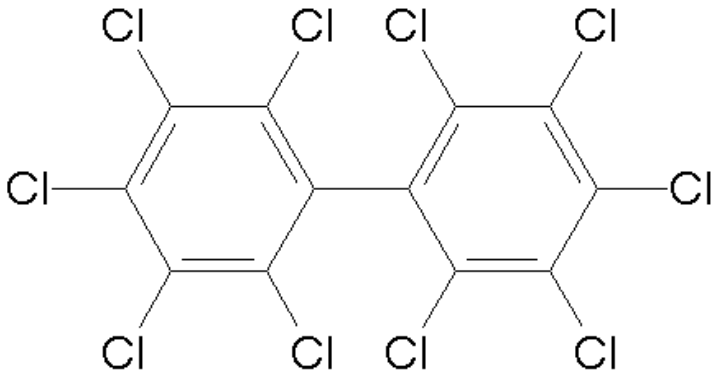
- **Nutrient Depletion**
  - The nitrogen cycle requires that the minerals taken up during plant growth will re-enter the soil when the plants die and decay.
  - If, through cultivation and harvesting, crops are continuously removed, the nutrients and minerals go along with them.
  - Nutrient depletion can be avoided by crop rotation over a number of years (and some off years where the crops are plowed back into the soil for nutrients).

E7.3 – Soil Pollutants

- E.7.3 **List** common organic soil pollutants and their sources. (1)
- Soil nutrient depletion is often addressed by the use of chemical fertilizers which contain nitrates (NO_3) and phosphates (PO_4)
- These excess nutrients can lead to environmental issues on their own
- As well as inorganic pollutants, organics can be soil pollutants as well.

E7.3 – Organic Soil Pollutants

- **<u>Persistent Chemical Pollutants</u>**:
- Chemicals such as pesticides and persistent industrial pollutants (like PCB's) can ruin soil by:
  - Killing small organisms including insects and earthworms, which play an important part in aerating the soil.
  - PCB: Polychlorinated Biphenyls



E7.3 – Organic Soil Pollutants

- **Volatile Organic Compounds**
  - Volatile and Semi-volatile organic compounds can be absorbed onto the surface of soil mineral grains, and can also be absorbed by organic matter in the soil.
  - They then slowly move through the soil and eventually contaminate groundwater

E7.3 – Polycyclic Organic Compounds

- During the incomplete combustion of fossil fuels, a class of carcinogenic compounds called **polycyclic aromatic hydrocarbons** (PAHs) can be formed
- These compounds include a number of benzene rings
- Also found in crude oil and tar deposits and can be released into the air during refining processes such as distillation and catalytic cracking.
- Bacteria cannot easily degrade PAHs so they remain in soil until they descend into groundwater.

E7.3 – Organotin Compounds

- **Organotin** compounds are those containing **tin** atoms joined to hydrocarbon substituents by carbon-tin covalent bonds
- Most common category is the triorganotins, with three hydrocarbon substituents.
- Used as bactericides and fungicides in industrial processes such as paper manufacture, and as wood preservatives
- Used in painting ship hulls as they prevent growth of microscopic plants (more more because toxic)